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DESIGN OF CARTESIAN TYPE AUTOMATED GLASS CLEANING SYSTEM FOR SKYSCRAPER'S

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ABSTRACT

Now a days it's been a trendy way to have high level of buildings and skyscraper's with glasses as front elevations. It is really acceptable that buildings with glasses provide good natural light and it also improves the outlook of the skyscrapers. But when it comes to the cleaning of all those glasses till to a particular height is fine manually, when we keep on going to high level the danger of the humans who are cleaning it keeps on increases and it's really a risking duty for the maintenance department. Now we took this problem and started working to find a suitable solution which is easy to operate and economical. So here we are proposing a design that can be used to clean the glasses attach to the building. In this paper we are presenting the design of a system that can be used in cleaning of glasses, covering a limited area and then the same system can be used to complete the work by simply repositioning the entire system which has a movable base along the glass wall. In this manner we can clean the entire glass attached to the Skyscraper's and buildings with in short time.

Key words: artificial body, handicapped people, Dassault Systems, Solid works, 3D modeling, Adams software.

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1. INTRODUCTION

Nowadays there exists increase in demand for the development of various service equipment to relieve human beings from hazardous or dangerous jobs and inspection of high pipes and walls. Window cleaning and washing makes the building's architectural glass free from dirt and dust. The traditional way of cleaning office or general store windows cannot be applied to high rise windows with huge sections of glass. Automation plays an important role because it achieves high safety and reduces man power, work load [5]. Currently there is no development of automated robot systems for cleaning the exterior walls of high rise buildings [3]. The reason behind this work is it is inaccessible to reach the window at such heights. It is really unsafe to clean the windows from outside as it requires special

tools in going up. This paper is based on an automated glass cleaner which is aimed to clean glasses of high-rise buildings or skyscraper, using Screw sliding mechanism.

1.1. Cleaning System is based on the following things

- Cartesian Co-ordinate: Generally Cartesian co-ordinate system consist of three degree of freedom, i.e., along the three axis's x, y and z. But here our system will work on two degree of freedom that are vertically and horizontally along y-axis and along x-axis respectively.
- Lead screw mechanism is at the middle of the system which is used to uplift a bar. This bar will go vertically due to the vertical motion of lead screw which is converting a rotation motion into linear motion.
- The bar which is uplifted by lead screw consist of belt drives which is mounted with brushes which is use to clean glasses. Brushes are attached to belt drives which have rotation motion in horizontal direction that is along x-axis with the help of a stepped motor.

1.2. Considerations

- The automated glass cleaner system design must to simple, economical and easy to use.
- The end-effector of glass cleaner must be adhesive and at a low pressure on glass wall surface on which is moving to avoid the windows breakages.
- The automated glass cleaner to realize a uniform screw sliding mechanism brush in concordance with a well-established working program to do the move cleaning-washing cycle.
- The size of automated glass cleaner will be design in such a way to allow the access on entirely cleaning surface of buildings windows [1]. The cleaning robot system is endowed with water injector and brushes to assure supplementary tasks, which it located in frontal way of robot moving.

1.3. Challenges of High Rise Window Cleaning System

- Cleaning a window in your room may only takes a piece of cloth, soapy water. When you are going to do the same thing on the 100th floor of a building at a dizzying height of more than half a kilometre above the ground, things change drastically.
- Environmental conditions at great heights are fairly different from what you experience on the ground level.
- We also have the risk at high altitudes of certain birds and bugs, they irritate workers, which is certainly not a good thing when you're hanging 100 stories up and doing your work.
- The pressure created by brush on the glass should be low enough to avoid any breakage of glass [4].
- Window cleaning, as you can see, is not an easy job. Presently, it is being considered to be one of the difficult and most dangerous jobs in the present working world.
- Workers report that anything from coffee to strawberry jam may be thrown from the higher stories, sticking to lower windows on the way down. When these substances get stuck and dried up they must be carefully removed in order to avoid the glass from damaging.

Major task of these kind of designs is lifting or lowering the entire setup. So, here are few designs that are used to lift the system.

1.4. Various Designs

1.4.1. Hydraulic lift

Hydraulic lift systems are basically used to lift or lower a load to the ground level. This system is heavy and slow in processing. Here, we thought of using hydraulic lift mechanism for lifting the body

mounted with a brush, which is mounted on a belt which is in continuous rotation motion. But Hydraulic lifts becomes erratic as the oil properties vary with the temperature. This is high heat producing and very expensive.

1.4.2. Rack and Pinion Mechanism

A rack and pinion is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. Torque can be converted to linear force by meshing a rack with pinion [2]. This mechanism can be used in lifting a single bar or rod vertically. This vertical rod is mounted with a horizontal bar which is mounted with a brush and a belt mechanism. But this mechanism has greater strain to individual parts, and the wear can cause leakage.

1.4.3. Belt and Pulley

Belt and pulley set up is like a belt is moving around a pulley with this mechanism we can be able to lift or lower the loads. So, here we thought of using this belt and pulley to lift or lower the body that has the set-up of brush. But later we thought when this system goes to real work the weight cannot be sustained by these. So, we moved to further ideas.

1.4.4. Proposed Design

As every mechanism has some advantages and disadvantage, we finally have come out with a simple design that which is totally based on the lead screw mechanism as shown in the Fig. 1. Lead screw column is situated in the middle of the system which is used to uplift a base of brush as shown in Fig. 2. This base will go vertically due to the vertical motion of lead screw which is converting a rotation motion into linear motion.

The base which is uplifted by lead screw consist of belt drives which is mounted with brushes which is use to clean glasses as shown in Fig. 4. Brushes are attached to belt drives which have rotation motion in horizontal direction that is along x-axis with the help of a stepped motor as shown in Fig. 3. Basically, this device initially cleans the glass window horizontally as a single stroke then once the first stroke is completed the brush slightly comes back and then the brush goes back to its initial position. While the brush reaches the initial position the base or the body of the brush come down a step according to the size of the brush. Once the brush comes to initial position and the base slides down a step then the brush comes forward and the system will start executing the second stroke of cleaning. Likewise step by step entire glass will be cleaned. As this design is for 3X3 feet which means 3 feet height and 3 feet width, after a stroke base slides down by a feet. Power and the torque required to raise or lower the body is give below in the calculations part. Required parts and approx. cost for the system has been shown in Table. 1

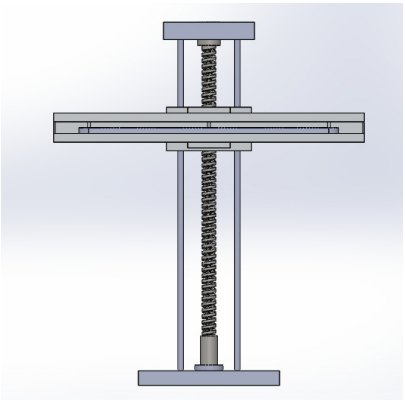

Figure 1 Front View of the Proposed Design

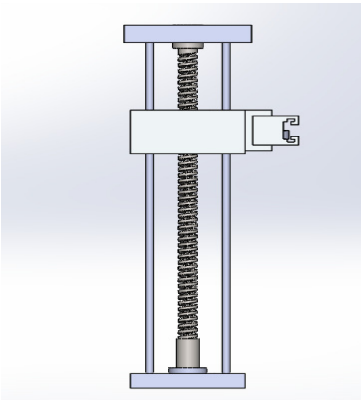

Figure 2 Side View of the Proposed Design

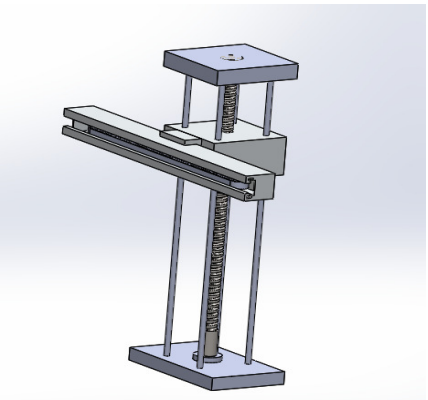

Figure 3 Isometric View of the Proposed Design

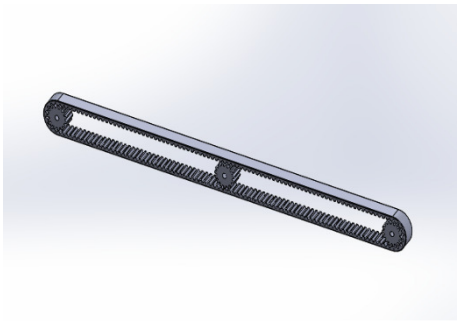

Figure 4 Isometric View of Belt and pulleys

Table 1 Required parts and cost observation table

S.no	Name of the Part	Type/Material	Quantity	Cost (Rupees)
1.	Lead Screw	Mild steel	1	2000
2.	Brush	Plastic/Polymers/Stainless steel body	2	200-500
3.	Motors	D.c Motor/Steppeed motors	2	2000
4.	Belts	Polymer	1	1500
5.	Pulleys	Aluminium/Brass/stainless steel/cast iron	3	1000-1500
6.	Sensors	Proximity switches	2	100-200

2. DESIGN CALCULATIONS

- Torque to raise the load.
- Torque to lower the load.
- Power generated.

2.1. Assumptions

Some assumptions of different parameters of the equipment are taken based on the standard values.

- Diameter of screw = 26mm
- Weights
  - Casing = 4Kg
  - Belt and gears = 0.5Kg
  - Screw = 6Kg
  - Load body = 2Kg
  - Others = 0.5Kg

    Total = 13Kg
- Length = 1000mm
- Brush size = 100mm (distance travelled in 1 second is 100mm)

2.2. Calculations

1. Force = mass × acceleration (1)

   = 13 × 9.8 = 127.4N

$$P = \frac{(f \times s)}{t} = (127.4 \times 0.1)/1 = 12.74 \text{ W} \quad (2)$$

2. Pick the motor

Peak linear velocity (V_{pk})

$$V_{pk} = 3s/2t = (3 \times 0.1) / (2 \times 1) = 0.15 \text{ m/sec} \quad (3)$$

3. Minimum pitch needed to keep the lead screw speed at about 1500 r.p.m.:

$$Pmin = \frac{Vpk \times 60}{Max\ screw\ up} = (0.15 \times 60)/1500 = 6\text{mm} \quad (4)$$

= considering it as 5mm as per the standards

4. Peak lead screw speed:

$$= (Vpk \times 60)/p = (0.15 \times 60)/0.005 = 1800 \text{ r.p.m} \quad (5)$$

$$W_{pk} = (1800 \times 2 \times 3.14)/60 = 188.49 \text{ rad/sec} \quad (6)$$

5. Total reflected inertia:

$J_s = 38.8 \times 10^{-7}$ Kg-m^2

$$J_l = m \times (p/(2 \times 3.14))^2 = 13 \times (0.005/2 \times 3.14)^2 \quad (7)$$

$= 8.232 \times 10^{-6}$ Kg-m^2

$$J_t = J_s + J_l = (38.8 \times 10^{-7}) + (8.232 \times 10^{-6}) \quad (8)$$

$= 1.211 \times 10^{-5}$ Kg-m^2

6. Shaft torque needed to accelerate the load inertia (T_a):

$$a = \frac{Vf - Vi}{tf - ti} = (0.15\text{-}0)/(0.333\text{-}0) \quad (9)$$

$= 0.4504$

$$\alpha = \frac{a \times 2 \times 3.14}{P} = (0.4504 \times 2 \times 3.14)/0.005 \quad (10)$$

$= 565.98$ rad/sec^2

$$Ta = Jt \times \alpha + \frac{cos\theta\ mgr \times P}{2 \times 3.14 \times ns} + \frac{sin\theta\ mg \times P}{2 \times 3.14 \times ns} \quad (11)$$

$= 1.211 \times 10^{-5} \times 565.98 + 0 + (\sin 90 \times 13 \times 9.8 \times 0.005)/2 \times 3.14 \times 0.86$

Ta = 0.1238 Nm

Tf = 0

Tg = 0.117 Nm

Td = -Ta = =-0.1238 Nm

7. RMs torque required at the stepper shaft:

$$Trms = \sqrt{\frac{(t1T1)^2 + (t2T2)^2 + (t3T3))^2}{t1 + t2 + t3 + dwell\ time}} \quad (12)$$

$=\sqrt{((0.333 \times (0.1238)^2 + 0.33 \times (0.117)^2 + 0.333 \times (-0.1238)^2)/ (0.333 + 0.333 + 0.333 + 0.5)}$

=0.099

8. Total power:

$$Ppk = Ta \times Wpk = 0.1238 \times 188.49 \quad (13)$$

$= 23.33$ W

$$Pavg = ((mgs)/t) \div ns = (13 \times 9.8 \times 0.1)/ 1 \quad (14)$$

$= 14.81$W

3. RESULTS

- Torque to raise the load = 2026.43 N-mm
- Torque to lower the load = 417.15 N-mm
- Power generated = 15W

4. CONCLUSION

The proposed design of Automated Glass Cleaning System is constructed as a proto type for covering a span of 3'x3' of the glass area, as the area increases the size of the lead screw get increased and also the base structure is being strengthened by providing suitable ribs for the support members. By implementing these type of systems the requirement of working labor at such risky areas will be reduced and also work will be completed in short time. Thus the dangerous accidents occurring during these operations can be reduced.

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